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THE PENNSYLVANIA STATE COLLEGE

The Graduate School

Department of Animal Nutrition

THE CHEMICAL COMPOSITION OF THE MAST FOOD PRODUCTS OF THE FORESTS OF PENNSYLVANIA

A Thesis

by

WALTER W. WAINIO

Submitted in partial fulfillment
of the requirements
for the degree of

MASTER OF SCIENCE

June, 1940

APPROVED: E. P. Jones

Head, Department of Animal Nutrition

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INTRODUCTION

In the interests of wild life conservation it is important to know the nutritive values of the food products of the forest, especially those which are available for the building up of nutritive reserves during the fall to carry the wildlife over the critical winter period. Only after the various mast and browse foods have been evaluated can we proceed, by proper forest management, to encourage the growth of the more desirable species: these are not necessarily the most nutritious ones, but rather those which combine high productivity and a capacity to resist decay with high nutritive value. Upon this knowledge, and that of the food habits of the animals of the forest, wildlife management must to a large extent depend.

This paper seeks to represent, by means of chemical analysis, the nutritive value of thirty-five mast products gathered in central Pennsylvania.

In making this study it was recognized that the possibilities of representing food values by chemical analysis are limited, and that the most significant information on the subject can be had only from the use of the food products by animals; but the mast foods are so extremely diverse in character - some being concentrated foods and capable of furnishing large parts of animals'

diets, while many more contain little nutriment, and normally serve only as minor components of highly complex diets - that the only practicable method of conducting a general survey of the subject was by chemical analysis.

A slight preliminary experience in offering mast foods to albino rats rendered obvious almost at once the impracticability of investigating the values of these products by any routine procedure of animal experimentation. Three rats were fed chestnut oak acorn flour ad libitum. They ate an average total of 18.5 grams in three days, and lost an average of 27 grams in weight during the same period. Extracting the flour with water on the steam bath for two hours to remove the tannin did not increase its consumption or decrease the weight losses. These trials discouraged any further attempts to use the rat as an experimental subject.

The conventional feed analysis in terms of moisture, total nitrogen, ether extract, crude fiber, ash and nitrogen-free extract, was accepted as the basic scheme. After considerable study of various other estimations that have been put onto a routine basis in recent years, it was decided to make additional determinations of tannin, cellulose, lignin, available nitrogen, calcium, magnesium and phosphorus. Each of these determinations will be critically evaluated in the section on "Methods".

COLLECTION AND STORAGE

The materials analyzed were collected by Dr. L. J. Bennett, Dr. P. F. English, T. Kuhn and R. McCain; and record was made (table 1) of the date and of the approximate location of collection when this latter information was available. Three additional products, namely, Italian chestnut, shell-bark hickory and hazelnut, were purchased in the open market and added to the collected mast foods. The Italian chestnut was included with the idea that the analysis of this product might serve approximately to represent the American chestnut if and when it shall regain its former prominence as a mast food.

As the materials were received they were either immediately prepared for analysis or were stored for a limited time in sealed containers within a refrigerator. The fruits and berries were stored at approximately 40°F and the nuts at temperatures below freezing.

Table 1

The Mast Products

Common Name*	Scientific Name*	Date Collected	Source	Portion Analyzed
Narrow-leaved Crab Apple	Malus coronaria	9-29-38	Seven Mountains, Huntingdon Co., Pa.	Whole fruit, without stems
American Mountain Ash	Sorbus americana	9-29-38	Seven Mountains, Huntingdon Co., Pa.	Whole berries
Bittersweet	Solanum Dulcamara	10-13-38	Centre Co., Pa.	Fruit, without calix
Blackberry	Rubus occidentalis	8-2-39	Barrens, Centre Co., Pa.	Whole berries
Bailey's Blackberry	Rubus Baileyanus	8-1-39	Centre Co., Pa.	Whole berries
Blueberry	Vaccinium sp.	8-1-39	Centre Co., Pa.	Whole berries
Wild Cherry	Padus virginiana	9-29-38	Seven Mountains, Centre Co., Pa.	(1) Whole fruit (2) Seeds
Black Chokeberry	Aronia melanocarpa	7-31-39	Barrens, Centre Co., Pa.	Whole berries

Table 1 (continued)

Common Name*	Scientific Name*	Date Collected	Source	Portion Analyzed
Red Chokeberry	Aronia arbutifolia	10-18-39	Barrens, Centre Co., Pa.	Whole berries
Cockspur Thorn	Crataegus Crus-Galli	10-13-38	Centre Co., Pa.	Whole fruit, without stems
Cucumber-tree	Magnolia acuminata	9-23-38	Allegheny National Forest Warren Co., Pa.	Whole fruit, including seeds, three-fourths ripe
Deerberry	Polycodium stamineum	8-29-39	Centre Co., Pa.	Whole fruit, unripe
Panicled Dogwood	Cornus femina	10-13-38	College Farm, Centre Co., Pa.	Whole berries
Red-osier Dogwood	Cornus stolonifera	9-25-39	Centre Co., Pa.	Whole berries, half ripe
American Elder	Sambucus canadensis	9-26-39	Oak Hall, Centre Co., Pa.	Whole berries
Frost Grape	Vitis cordifolia	10-13-38	Huntingdon Co., Pa.	Whole fruit
Hackberry	Celtis occidentalis	11-2-39	Centre Co., Pa.	Whole berries

Table 1 (continued)

Common Name*	Scientific Name*	Date Collected	Source	Portion Analyzed
Black Haw	Vibernum prunifolium	9-29-38	Seven Mountains, Centre Co., Pa.	Whole berries, unripe
Mountain Holly	Nemopanthus mucronata	8-10-39	Bear Meadows, Centre Co., Pa.	Whole berries
Juneberry	Amelanchier canadensis	7-7-39	Centre Co., Pa.	Whole berries
Nannyberry	Vibernum Lentago	9-25-39	Centre Co., Pa.	Whole berries, 95% ripe
Spice-bush	Benzoin aestivale	9-29-38	Seven Mountains, Huntingdon Co., Pa.	(1) Outer fleshy integument (2) Seeds
Smooth Upland Sumac	Rhus glabra	9-29-38	Seven Mountains, Centre Co., Pa.	Whole berries
Staghorn Sumac	Rhus hirta	10-18-39	Barrens, Centre Co., Pa.	Whole berries
Virginia Winterberry	Ilex verticillata	10-17-39	Bear Meadows, Centre Co., Pa.	Whole berries
Fetid Buckeye	Aesculus glabra	9-25-39	Centre Co., Pa.	Nut meats
Italian Chestnut	Castanea vulgaris		Open market	Nut meats

Table 1 (continued)

Common Name*	Scientific Name*	Date Collected	Source	Portion Analyzed
Hazel-nut	Corylus americana	9-3-38	Seven Mountains, Centre Co., Pa.	Nut meats
Shell-bark Hickory	Hicoria ovata		Open market	Nut meats
Red Oak	Quercus rubra	10-20-38	Allegheny National Forest Warren Co., Pa.	Nut meats, with inner integument
Rock Chestnut Oak	Quercus Prinus	10-7-38	Seven Mountains, Huntingdon Co., Pa.	Nut meats, with inner integument
Scrub Oak	Quercus ilicifolia	9-29-38	Seven Mountains, Huntingdon Co., Pa.	Nut meats, with inner integument
Scrub Chestnut Oak	Quercus prinoides	9-25-39	Barrens, Centre Co., Pa.	Nut meats, with inner integument
White Oak	Quercus alba	10-13-38	Nittany Mountain, Centre Co., Pa.	Nut meats, with inner integument
Black Walnut	Juglans nigra		Open Market	Nut meats

*Authority: N. L. Britton and A. Brown 1936 An illustrated flora of the Northeastern United States, Canada and the British Possessions, vols. I, II, and III. The New York Botanical Garden.

PREPARATION FOR ANALYSIS

Each individual product was separated from its accompanying extraneous material (leaves, stems, twigs, or shells), and a weighed quantity of the portion to be analyzed (table 1) was placed in an oven to dry. In the case of the wild cherry, separate analyses were made of the whole berries and of the seeds; and in the case of spice-bush berries separate analyses were made of the outer fleshy integument and the seeds. The figures for the pulp and skin of the wild cherry and the whole spice-bush berry were calculated from the components of each that were subjected to analysis.

The fruits and berries were dried in a Freas air-oven at a temperature of approximately 50°C. The fruit of the crab apple, cockspur thorn, deerberry and cucumber-tree were sliced prior to being dried. The nut meats were chopped into quarter-inch cubes, and dried for 48 hours in a Weber vacuum oven at room temperature and under reduced pressure.

The oven-dry materials were then transferred to a screened cabinet in which they were allowed to come to equilibrium with the moisture of the air. After 7 to 10 days they were weighed and the loss of moisture from the fresh to the air-dry state was recorded.

The air-dry samples were ground in a meat chopper, and then extracted for 48 hours, the oily substances (nuts, spice-bush, berries, etc.) with ether, and the sugary substances (blueberry, blackberry, etc.) with alcohol. The dry residues were then ground in a micro Wiley mill, to pass a 20-mesh sieve, and were then recombined, quantitatively, with their respective extracts.

The recombined materials were again dried in the Freas air-oven to remove the solvent, and were then rubbed through a 20-mesh sieve. Finally they were placed in the screened cabinet, and allowed once more to come into equilibrium with the moisture of the air, and after 7 to 10 days were bottled and sealed in readiness for analysis.

METHODS OF ANALYSIS

Determination of Moisture

The determination used was the official A.O.A.C. method (1), which consists of drying in a vacuum desiccator, without heat, in the presence of sulfuric acid. The drying time was lengthened to twenty-one days because previous work had shown that the more dense products continued to lose weight until 14 to 21 days had passed.

This method has one very obvious advantage over those methods that employ heat, in that there is no appreciable oxidation of the heat-labile substances. It is apparent even from the color changes that occur in an oven at 100°C (general darkening) that oxidative changes do take place. Furthermore, if the sample from the moisture determination is to be used for the determination of ether extract as was done in this instance, then the desiccator method becomes doubly advantageous because lipids oxidize rather readily at high temperatures in the presence of oxygen.

Determination of Crude Protein

The official A.O.A.C. Kjeldahl-Gunning-Arnold method (1) was used for the determination of total nitrogen and modified to include 4% boric acid as the receiving liquid in distillation. Winkler (19) was the first to propose the

use of boric acid and since 1913 it has gained wide favor. Its advantage lies in that only one standard solution (standard acid) is required, although this advantage is offset in part by the fact that the end-point during titration is less sharp.

The factor used to convert total nitrogen to crude protein was the usual 6.25.

Determination of Ether Extract

Ether extract (crude fat) was determined by the official-direct method of the A.O.A.C. (1) for grain and stock feeds. The samples from the moisture determination (desiccator dried) were used for this purpose.

Because it was known that the ether extracts contained not only fat and fatty acids, but also variable amounts of chlorophyll, xanthophyll, carotene, lecithins, waxes, alkaloids, and sterols, it was thought significant to consider some other, more refined, method. The method selected for study was the Horwitt, Cowgill and Mendel (7) modification of the Kumagawa and Suto (9) saponification technic. Briefly, it consists of an extraction with alcohol-ether (4 + 1), a saponification with 10 N NaOH, subsequent acidification with HCl and extractions with petroleum ether and N/10 KOH to separate the fatty acids

from the non-fat fractions.

Even before any attempt had been made to apply this method to the mast products, two important questions arose. The first was: how completely would the alcohol-ether mixture extract the fats and fatty acids when the total hot-plate extraction time was only twenty-five minutes (100 cc. for 10 min., 75 cc. for 5 min. and 25 cc. twice for 5 min. each)? Although this question remained unanswered it seemed that here was a valid criticism if the method was to be applied to such a variety of materials as was offered by these mast products. The second question was: how well would the whole procedure lend itself to routine handling? Inspection of the printed procedure suggested that eleven extractions and decantations and one evaporation and acidification in addition to the initial alcohol-ether extraction, saponification and acidification were too numerous for routine work. The method, therefore, was considered to be unsatisfactory in this instance.

Determination of Crude Fiber

The crude fiber fraction has ever been a source of irritation to the feed analyst. The very impirical nature of the fraction, as a consideration of the restrictions which govern its determination will reveal, has from the very first, suggested that a more exact partitioning into its

component parts is desirable. The fraction is now known to consist of lignin, cellulose and hemicelluloses. It cannot be assumed, however, that each of these three components is present in its entirety in the crude fiber fraction, for it is known that weak acids and alkalies do have some limited effect on cellulose and an even greater effect on hemicelluloses. Lignin apparently is unaffected. Furthermore, it has become evident that native celluloses (and hemicelluloses) from different sources vary greatly in their resistance to acids and alkalies, not only in the presence of lignin, which usually exerts a protective influence over the carbohydrate, but also in its absence.

These objections to the conventional method led to the study of the enzymatic method of Remy (15), as modified by Horwitt, Cowgill and Mendel (7), with the intention of using it, if applicable, to evaluate more clearly the crude fiber fraction. The method in detail is as follows: "Three grams of dried spinach were incubated with 0.5 gm. of pepsin in 500 cc. of N/10 hydrochloric acid for 48 hours. The mixture was then neutralized to pH 7 with sodium hydroxide, brought to pH 4.5 with hydrochloric acid and treated with 0.1 gm. of taka-diastase for 48 hours. At the end of this time the digest was filtered, the residue returned to the digestion flask and treated with 500 cc. of a faintly alkaline solution containing an extract of

0.5 gm. of trypsin. This was allowed to incubate for 4 days, toluene being added daily. The residue from this digest was washed with water until the filtrate no longer gave a test for chloride, then with alcohol and ether, and dried at 110°C. to constant weight."

Before any preliminary determinations were made the question arose of the tannin interfering with the enzyme action. In addition to a possible paralyzing action on the enzymes, there was introduced the new factor of the precipitation of proteins by the tannin (the tanning reaction). Qualitative tests with an aqueous extract of rock chestnut oak acorn flour and a water solution of trypsin showed that the two do form a precipitate. Any organic precipitate in this instance would be measured as crude fiber and invalidate the results. It became necessary, therefore, to study the effect of the removal of the tannin, and comparative determinations were made on samples of extracted and unextracted chestnut oak acorn flour. The extractions were made by boiling on a steam bath for two hours with 300 cc. of distilled water and then filtering and washing. The results are shown below (table 2) and they indicate that the extraction very definitely improved the determination.

Table 2

Comparison of Extracted and Unextracted Samples of Chestnut Oak Acorn Flour

Nature of Preliminary Treatment	% Crude Fiber	
Extracted for two hours on a steam bath with 300 cc. of distilled water. Filtered and washed.	9.00 8.77 9.40	Av. 9.06
None	49.33 46.50 47.15	Av. 47.66

The physical nature of the extracted samples suggested another possibility that had not come to mind before - that the improved value was due, not only to the removal of the tannins, but also to the gelatinization of the starch during boiling. This additional question indicated that there were too many unanswered problems to allow of an intelligent application of this method.

The only crude fiber fraction that was determined, therefore, was the official crude fiber of the A.O.A.C. (1).

Determination of Total Ash

Ash was determined by the official A.O.A.C. (1) method for ash in fruits and fruit products.

Determination of Nitrogen-free Extract

The method for determining the so-called "available carbohydrate" of Horwitt, Cowgill and Mendel (7) was under consideration briefly as a refinement of the method for nitrogen-free extract, but because it had been previously found that many of the masts contained tannin, the possibility of interference with enzyme action presented itself. Oparin and Kursanov (14) have reported that enzyme determinations on tannin-containing leaves are very difficult because the soluble tannins inactivate the enzymes. Zlatarov and Popov (20) have found more recently that tannin (tannic acid-0.001 gm.) has a strong paralyzing action on enzymes. Whether this interference could be extensive enough to be important when an excess of enzyme is present must remain a question to be answered by some future work.

The nitrogen-free extract is the percent of sample that remains after the sum of the percentages of moisture, crude protein, ether extract, crude fiber and total ash have been subtracted from one hundred.

Determination of Available Protein

The search for a more exact determination of the nutritive value of the protein contained in these mast products led to the adoption of the method of Horwitt, Cowgill and Mendel (6) for "Available Nitrogen". The determination is essentially one for amino and protein nitrogen because the fat soluble, the nitrate and amide and the ammonia nitrogen are all removed.

The method, in detail, is as follows: "Extract 2 gm. of the dried finely comminuted substance three times with 50 cc. portions of a hot alcohol-ether mixture containing 80% alcohol and 20% ether. Transfer the residue from this extraction to a Kjeldahl flask, and mix with 50 cc. water, 2 gm. of ferrous sulphate and 5 cc. of H_2SO_4 (1 + 1). After the reaction has ceased, boil the mixture slowly for about 5 minutes and cool. Add water, to make a volume of about 100 cc., and about 5 gm. of magnesium oxide. Boil the mixture until almost dry, cool and carefully add 25 cc. of concentrated sulfuric acid and 1 drop selenium oxide. From this point on the procedure is the same as in the Kjeldahl determination for nitrogen. Additional potassium sulfate is not necessary because the magnesium sulfate formed is equally efficient in raising the boiling point of the mixture".

An application of this method reveals that it is not adaptable to a routine analysis of mast products. Each boiling or digestion is accompanied by such excessive frothing that from an hour to an hour and a half is spent in the closest attendance (during each separate boiling) to prevent loss of the sample. From 6 to 8 hours are needed to carry through a set of twelve samples, i.e., four products, each in triplicate.

Available nitrogen was converted to available protein by use of the factor 6.25.

Determination of Lignin

The method of Ross and Hill (16) as modified by Crampton and Maynard (4), and again by Crampton (3) was used in the determination of lignin. "Place the oven-dry, ether extracted residue from a 1 gm. sample of feed (or feces) in a 50 cc. glass stoppered Erlenmeyer and add 40 cc. of a 2.0% solution of pepsin in N/10 HCl. Digest for 12 hours at 40°C., shaking frequently especially during the first 4 or 5 hours. Recover the non-digested residue by filtration through bolting silk and wash successively with hot water, hot alcohol, hot benzene, hot alcohol, and ether. Transfer the washed residue to a 100 cc. beaker, and remove the last traces of ether with mild heat. Moisten the residue with 4 cc. of 40% formaldehyde. Then

add 4 cc. of 72% H_2SO_4, and allow it to penetrate the sample (2 minutes). Add 6 cc. of concentrated H_2SO_4 and stir vigorously with a glass rod to aid in solution of the sample which should be complete in 10 to 15 minutes. Partially immerse the beaker in a cold water bath, if necessary, to prevent the temperature from rising above about 70°C. When dissolved pour the whole into 500 cc. of distilled water in an 800 cc. beaker to which has been added a small quantity of pre-ignited "Celite Analytical Filter-Aid". Boil gently for 15 minutes, after which the solution should clear and the lignin settle in granular form. Filter through a Gooch crucible which has had a thin layer of "Celite Filter-Aid" spread over the asbestos pad. Wash with not less than 200 cc. of 5% HCl. Dry at 110°C and determine lignin by loss on ignition".

A cellulose determination on the purified lignin of the black haw showed that the decomposition by the formaldehyde-sulfuric acid mixture had been fairly complete: approximately 1% of the total lignin appeared as cellulose.

Haas and Hill (5) state in their text that formaldehyde and tannin are supposed to react to form insoluble, cork-like precipitates which are insoluble in Schweitzer's reagent and strong sulfuric acid. This might suggest that any future modification of the above

method should include a water extraction, prior to the pepsin-HCl digestion, to remove the tannins.

Determination of Cellulose

Cellulose was determined by the method of Kurschner and Hanak (10) as applied by Crampton and Maynard (4) to animal feeds. The procedure is as follows: "Place a 1 gm., air dry sample in a 150 cc. round-bottomed, wide-necked flask fitted with a reflux condenser. Add 15 cc. of 80% acetic acid and 1.5 con. HNO_3. Boil gently for 20 minutes. Transfer the sample and liquid to a 50 cc. centrifuge tube; add about 20 cc. of alcohol and centrifuge 10 minutes. Decant the liquid. Wash (in centrifuge tube) with alcohol. Transfer the residue (with aid of a stream of alcohol from a wash bottle) into an alundum crucible and wash successively with hot benzene, hot alcohol, and ether - using suction. Dry. Calculate cellulose as loss on ignition. Our experience has shown this method to give reproducible results."

A lignin determination on the cellulose of the black haw revealed that a considerable portion of the lignin had not been removed during the acetic acid-nitric acid digestion. The percent of cellulose in the air-dry sample

was 7.17 and of this total approximately 16% appeared as lignin. Whether this means that the acid digestion is incomplete or that the lignin value is an apparent one must remain to be solved by future work.

The Determination of Tannin

One of the general characteristics of the group of widely distributed plant principles which are known by the generic term tannin is their ability to precipitate proteins, i.e., their astringency. For this reason it was thought that it would be of considerable importance to have more exact knowledge concerning the tannin content of these mast products, especially as their palatability might be influenced thereby. Clarke, Frey and Hyland (2) have observed that the total tannin content of the leaves of Lespedeza sericea varies from 7.5 to 18.0 during the growth season, while the feeding trials of Nevens (13) with dairy cows have shown that lespedeza hay is not as palatable as alfalfa hay.

It may even be that at times the tannin might prove to be detrimental to the health of the animals. Whereas small quantities of tannin are generally assumed to be tonic and beneficial, large quantities are definitely irritating and may lead to gastroenteritis (18). Should the winter food reserves run so low that the animals have

to turn to unpalatable foods through dire necessity, then the tannin content may become a complicating factor. As for instance, Sanders (17) reports: "Dr. I. B. Boughton, Veterinarian, Texas Agricultural Experiment Station, Sonora, Texas, diagnosed the death of twenty-six adult cows and four calves on the Bundy-Ross ranch in Kimble Co. in April as having been caused by 'Bud Disease', which is another name for the illness caused by the eating of oak leaves and buds. Under ordinary conditions livestock do not eat excessive amounts of the new oak growth".

Tannin was determined by the official A.O.A.C. (1) method for tannin in spices and this method was selected because it could be readily applied to such a variety of materials as presented by these mast products. Mitchell (11) has criticized this method (the permanganate method) in a recent review, but probably no more severely than the other methods that he lists as being in common use today. The general impression that one receives upon reading Mitchell's survey is that each method has its limitations and that these are chiefly due to insufficient knowledge concerning the structure and action of the tannins. The precipitation methods are not always specific for the tannins and the oxidation-reduction methods, which include the permanganate method, generally need standardization for each kind of tannin.

Determination of Calcium, Magnesium and Phosphorus

Calcium and magnesium were determined by the tentative A.O.A.C. (1) methods for these minerals in fruits and fruit products.

Phosphorus was determined by the official, gravimetric, A.O.A.C. (1) method for phorphorus in fertilizers.

RESULTS OF ANALYSES

Table 3

Analysis of Mast Products

(Dry basis)

	Crude Protein	Ether Extract	Crude Fiber	Total Ash	N-free Extract
	%	%	%	%	%
Narrow-leaved Crab Apple	5.56	6.19	16.95	3.16	68.14
American Mountain Ash	5.44	4.66	8.02	3.10	78.78
Bittersweet	15.19	28.77	8.26	3.44	44.34
Blackberry	8.19	7.58	21.43	3.12	59.68
Bailey's Blackberry	6.75	6.08	24.14	4.31	58.72
Blueberry	4.19	3.80	9.67	1.44	80.90
Wild Cherry (whole berry)	6.75	6.26	20.85	2.84	63.30
" " (seed)	13.13	15.70	50.85	1.57	18.75
" " (pulp & skin)	5.13	3.89	13.31	3.15	74.52
Black Chokeberry	5.00	3.44	12.56	2.71	76.29
Red Chokeberry	5.25	3.80	9.24	2.52	79.19
Cockspur Thorn	2.81	3.29	32.83	3.69	57.38
Cucumber-tree	7.50	21.99	28.39	4.90	37.22
Deerberry	3.75	5.45	11.17	1.62	78.01
Panicled Dogwood	6.88	26.73	25.76	3.36	37.27
Red-osier Dogwood	6.94	12.02	26.42	3.40	51.22

Table 3 (continued)

	Crude Protein	Ether Extract	Crude Fiber	Total Ash	N-free Extract
	%	%	%	%	%
American Elder	11.06	12.94	17.93	5.52	52.55
Frost Grape	5.38	0.87	13.43	2.75	77.57
Hackberry	8.25	4.37	7.09	27.35	52.94
Black Haw	4.13	11.93	10.28	2.58	71.08
Mountain Holly	7.06	7.71	18.45	2.23	64.55
Juneberry	8.06	4.45	12.27	3.70	71.52
Nannyberry	4.13	8.88	7.18	2.06	77.75
Spice-bush (whole berry)	11.94	50.73	5.23	5.74	26.36
" " (seed)	18.19	56.21	7.45	2.20	15.95
" " (pulp & Skin)	8.56	47.82	4.05	7.62	31.95
Smooth Upland Sumac	4.13	11.23	34.90	2.45	47.29
Staghorn Sumac	5.44	14.54	30.31	3.01	46.70
Virginia Winterberry	6.13	5.10	15.57	2.62	70.58
Fetid Buckeye	12.63	6.13	2.48	4.81	73.95
Italian Chestnut	6.88	3.34	2.42	3.05	84.31
Hazel-nut	26.50	61.40	2.16	2.76	7.18
Shell-bark Hickory	13.31	74.36	1.51	2.01	8.81
Red Oak	6.56	20.81	3.10	2.42	67.11
Rock Chestnut Oak	6.94	5.05	2.62	2.22	83.17
Scrub Oak	10.25	19.99	3.00	2.12	64.64
Scrub Chestnut Oak	7.63	6.30	2.42	1.98	81.67
White Oak	6.25	6.32	2.47	2.64	82.32
Black Walnut	29.25	60.23	1.03	2.76	6.73

Table 3 (continued)

	Available Protein	Lignin	Cellulose	Tannin	Calcium	Magnesium	Phosphorus
	%	%	%	%	%	%	%
Narrow-leaved Crab Apple	4.00	11.89	15.48	4.71	0.02	0.09	0.17
American Mountain Ash	4.25	9.57	6.87	4.08	0.10	0.13	0.16
Bittersweet	11.88	8.98	10.22	1.35	0.27	0.29	0.36
Blackberry	6.63	31.73	13.52	1.72	0.15	0.14	0.21
Bailey's Blackberry	5.56	28.58	15.49	2.04	0.12	0.17	0.12
Blueberry	2.75	13.85	7.97	1.28	0.04	0.07	0.07
Wild Cherry (whole berry)	5.75	18.65	12.92	0.60	0.16	0.07	0.16
" " (seed)	11.25	38.29	25.28	-	0.18	0.08	0.19
" " (pulp & skin)	4.31	13.70	9.81	0.75	0.16	0.07	0.16
Black Chokeberry	4.19	39.80	9.80	3.78	0.25	0.12	0.13
Red Chokeberry	4.38	36.13	8.48	7.31	0.22	0.21	0.13
Cockspur Thorn	2.56	20.44	23.32	3.39	0.42	0.10	0.14
Cucumber-tree	6.19	16.56	19.84	2.60	0.23	0.14	0.20
Deerberry	2.50	11.46	8.57	1.71	0.05	0.05	0.05
Panicled Dogwood	5.88	20.62	11.21	1.46	0.21	0.09	0.15
Red-osier Dogwood	5.56	27.12	12.01	1.58	0.27	0.19	0.22
American Elder	8.38	15.36	10.54	2.71	0.13	0.21	0.36
Frost Grape	4.19	14.50	7.45	1.99	0.06	0.08	0.15
Hackberry	7.13	8.04	5.89	0.82	12.42	0.49	0.22
Black Haw	3.69	24.68	7.70	5.94	0.05	0.08	0.13
Mountain Holly	5.81	17.27	14.49	0.96	0.13	0.13	0.12
Juneberry	6.50	16.03	14.93	0.41	0.34	0.21	0.19
Nannyberry	3.63	32.32	6.69	1.57	0.12	0.04	0.14
Spice-bush (whole berry)	9.94	4.04	5.98	1.35	-	0.13	0.30

Table 3 (continued)

	Available Protein	Lignin	Cellulose	Tannin	Calcium	Magnesium	Phosphorus
	%	%	%	%	%	%	%
Spice-bush (seed)	17.06	5.21	4.91	0.58	-	0.16	0.38
Spice-bush (pulp & skin)	6.13	3.41	6.54	1.75	-	0.11	0.26
Smooth Upland Sumac	3.56	22.56	27.99	6.89	0.16	0.07	0.16
Staghorn Sumac	4.88	21.66	27.50	4.41	0.30	0.15	0.25
Virginia Winterberry	5.31	9.49	12.61	0.68	0.13	0.18	0.10
Fetid Buckeye	11.44	1.42	3.21	-	0.11	0.16	0.52
Italian Chestnut	5.69	0.38	3.69	0.19	-	0.07	0.15
Hazel-nut	23.88	1.22	3.91	-	0.29	0.17	0.40
Shell-bark Hickory	12.13	0.74	2.63	0.48	Tr.	0.16	0.37
Red Oak	6.13	2.99	4.14	9.77	Tr.	0.07	0.14
Rock Chestnut Oak	6.25	2.50	3.53	10.43	Tr.	0.09	0.15
Scrub Oak	9.56	4.00	3.76	11.28	Tr.	0.14	0.19
Scrub Chestnut Oak	6.88	6.56	3.19	4.43	0.07	0.08	0.15
White Oak	6.00	2.64	3.24	5.58	Tr.	0.10	0.16
Black Walnut	27.06	0.87	2.01	0.25	Tr.	0.27	0.59

Table 4

Analysis of Mast Products

(Fresh basis)

	Moisture	Crude Protein	Ether Extract	Crude Fiber	Total Ash	N-free Extract
	%	%	%	%	%	%
Narrow-leaved Crab Apple	87.0	0.75	0.80	2.20	0.41	8.84
American Mountain Ash	73.7	1.44	1.23	2.11	0.82	20.70
Bittersweet	66.3	5.13	9.69	2.78	1.16	14.94
Blackberry	80.9	1.56	1.45	4.10	0.60	11.39
Bailey's Blackberry	79.6	1.38	1.24	4.93	0.88	11.97
Blueberry	85.3	0.63	0.56	1.42	0.21	11.88
Wild Cherry (whole berry)	64.5	2.38	2.22	7.41	1.01	22.48
" " (seed)	11.5	11.56	13.90	45.02	1.39	16.63
" " (pulp & skin)	75.6	1.25	0.95	3.25	0.77	18.18
Black Chokeberry	75.6	1.25	0.84	3.07	0.66	18.58
Red Chokeberry	65.6	1.81	1.31	3.18	0.87	27.23
Cockspur Thorn	62.0	1.06	1.25	12.48	1.40	21.81
Cucumber-tree	73.0	2.00	5.94	7.67	1.32	10.07
Deerberry	83.2	0.63	0.92	1.88	0.27	13.10
Panicled Dogwood	57.0	2.94	11.49	11.07	1.45	16.05
Red-osier Dogwood	68.4	2.19	3.79	8.34	1.07	16.21
American Elder	76.4	2.63	3.06	4.24	1.30	12.37
Frost Grape	69.6	1.63	0.26	4.08	0.84	23.59
Hackberry	21.4	6.50	3.43	5.57	21.50	41.60
Black Haw	57.1	1.75	5.12	4.41	1.11	30.51
Mountain Holly	59.2	2.88	3.15	7.53	0.91	26.33

Table 4 (continued)

	Moisture	Crude Protein	Ether Extract	Crude Fiber	Total Ash	N-free Extract
	%	%	%	%	%	%
Juneberry	80.7	1.56	0.86	2.37	0.71	13.80
Nannyberry	53.8	1.94	4.11	3.32	0.95	35.88
Spice-bush (whole berry)	62.3	4.50	19.14	1.97	2.17	9.92
" " (seed)	28.4	13.00	40.26	5.33	1.58	11.43
" " (pulp & skin)	77.8	1.94	10.62	0.90	1.69	7.05
Smooth Upland Sumac	8.1	3.81	10.32	32.07	2.25	43.45
Staghorn Sumac	8.0	5.00	13.37	27.87	2.77	42.99
Virginia Winterberry	68.6	1.94	1.60	4.88	0.82	22.16
Fetid Buckeye	52.7	6.00	2.90	1.17	2.27	34.96
Italian Chestnut	33.1	4.63	2.23	1.62	2.04	56.38
Hazel-nut	2.6	25.81	59.80	2.10	2.69	7.00
Shell-bark Hickory	2.2	13.00	72.72	1.48	1.97	8.63
Red Oak	38.2	4.06	12.87	1.92	1.50	41.45
Rock Chestnut Oak	50.1	3.44	2.52	1.31	1.11	41.52
Scrub Oak	42.0	5.94	11.61	1.74	1.23	37.48
Scrub Chestnut Oak	44.2	4.25	3.52	1.35	1.11	45.57
White Oak	47.3	3.31	3.33	1.30	1.39	43.37
Black Walnut	2.9	28.38	58.48	1.00	2.68	6.56

Table 4 (continued)

	Available Protein	Lignin	Cellulose	Tannin	Calcium	Magnesium	Phosphorus
	%	%	%	%	%	%	%
Narrow-leaved Crab Apple	0.50	1.55	2.01	0.61	<0.01	0.01	0.02
American Mountain Ash	1.13	2.52	1.81	1.07	0.03	0.03	0.04
Bittersweet	4.00	3.02	3.44	0.45	0.09	0.10	0.12
Blackberry	1.25	6.06	2.58	0.33	0.03	0.03	0.04
Bailey's Blackberry	1.13	5.84	3.17	0.42	0.02	0.04	0.02
Blueberry	0.50	2.04	1.17	0.19	0.01	0.01	0.01
Wild Cherry (whole berry)	2.06	6.63	4.59	0.21	0.06	0.02	0.06
" " (seed)	9.94	33.90	22.38	-	0.16	0.07	0.17
" " (pulp & skin)	1.06	3.35	2.40	0.18	0.04	0.02	0.04
Black Chokeberry	1.00	9.72	2.39	0.92	0.06	0.03	0.03
Red Chokeberry	1.50	12.43	2.92	2.51	0.07	0.07	0.05
Cockspur Thorn	1.00	7.77	8.86	1.29	0.16	0.04	0.05
Cucumber-tree	1.69	4.48	5.36	0.70	0.06	0.04	0.06
Deerberry	0.44	1.93	1.44	0.29	0.01	0.01	0.01
Panicled Dogwood	2.50	8.86	4.82	0.63	0.09	0.04	0.07
Red-osier Dogwood	1.75	8.56	3.79	0.50	0.09	0.06	0.07
American Elder	2.00	3.63	2.49	0.64	0.03	0.05	0.08
Frost Grape	1.25	4.41	2.27	0.61	0.02	0.03	0.05
Hackberry	5.56	6.32	4.63	0.64	9.76	0.38	0.17
Black Haw	1.56	10.59	3.31	2.55	0.02	0.03	0.06
Mountain Holly	2.38	7.04	5.91	0.39	0.05	0.05	0.05
Juneberry	1.25	3.10	2.88	0.08	0.07	0.04	0.04
Nannyberry	1.69	14.94	3.09	0.73	0.05	0.02	0.06
Spice-bush (whole berry)	3.75	1.52	2.26	0.51	-	0.05	0.11
" " (seed)	12.25	3.74	3.52	0.42	-	0.11	0.27

Table 4 (continued)

	Available Protein	Lignin	Cellulose	Tannin	Calcium	Magnesium	Phosphorus
	%	%	%	%	%	%	%
Spice-bush (pulp & skin)	1.38	0.76	1.45	0.39	-	0.03	0.06
Smooth Upland Sumac	3.25	20.73	25.72	6.33	0.15	0.06	0.15
Staghorn Sumac	4.50	19.92	25.29	4.06	0.28	0.14	0.23
Virginia Winterberry	1.69	2.98	3.96	0.21	0.04	0.06	0.03
Fetid Buckeye	5.44	0.67	1.52	-	0.05	0.08	0.25
Italian Chestnut	3.81	0.25	2.47	0.13	-	0.05	0.10
Hazel-nut	23.25	1.19	3.81	-	0.28	0.17	0.39
Shell-bark Hickory	11.88	0.72	2.57	0.47	Tr.	0.16	0.36
Red Oak	3.81	1.85	2.56	6.04	Tr.	0.05	0.08
Rock Chestnut Oak	3.13	1.25	1.76	5.20	Tr.	0.04	0.08
Scrub Oak	5.56	2.32	2.18	6.55	Tr.	0.08	0.11
Scrub Chestnut Oak	3.81	3.66	1.78	2.47	0.04	0.04	0.09
White Oak	3.13	1.39	1.71	2.94	Tr.	0.05	0.08
Black Walnut	26.25	0.84	1.95	0.24	Tr.	0.26	0.57

DISCUSSION OF RESULTS

General

The results of the chemical analyses of the mast products are given in table 3 as expressed on the dry basis, and in table 4 on the fresh basis. Comments will be made on the former alone, since from the nutritive point of view the moisture contained in the materials is simply a variable diluent.

The content of available protein was less than the crude protein in all products, indicating the presence of some fat-soluble, nitrate, amide or ammonia nitrogen. The error of regarding non-protein as protein nitrogen is of less significance when the foods are used by ruminants than when they are used by non-ruminants, because the former have the capacity to utilize nitrogen from sources other than protein - presumably by virtue of the synthetic capacities of the bacteria of rumen.

The sum of the values for lignin and cellulose was invariably higher (124 to 543%) than the single figure for crude fiber. This may be due to a loss of cellulose during the acid and alkali digestions involved in the determination of crude fiber; or the values for lignin and cellulose may conceivably be high due to undetermined impurities.

The values for nitrogen-free extract are more indefinite than usual because they include the questionable tannin fraction, which reaches a maximum of 11.28 per cent in the acorn of the scrub oak.

Very little can be said concerning the nutritive availability of these mast products because of the lack of directly applicable evidence. It is only possible to generalize and to say that if their digestibility were similar to that of the grain concentrates by ruminants then it could be expected that the protein would be 70 to 90% digestible, the fat 75-100%, the fiber 50-90%, and the nitrogen-free extract 80-90% (Morrison, 12). These averages, however, may fail by far to represent the facts in individual instances, as the following figures for the digestibility of whole acorns by ruminants will show (Morrison, 12): protein 20%, fat 84%, fiber 15% and nitrogen free extract 50%. One additional set of approximations is available from the work of Jaffa (8), who found, in experiments with human beings, that the coefficients of digestibility of a diet of fruits and nuts were, protein 90%, fat 85% and carbohydrate 95%.

Fruits and Berries

The narrow-leaved crab apple is mainly a carbohydrate food, being relatively poor in protein, ether

extract and mineral nutrients, and rich in nitrogen-free extract. The high contents of cellulose, lignin and tannin are more suggestive of bark than of fruit. The product, however, is characterized by a considerable value for purposes of maintenance.

The berries of the mountain ash and two chokeberries are of a nutritive character similar to the crab apple, although they differ somewhat in their contents of lignin and cellulose. Since these products contain nearly 80 per cent of nitrogen-free extract, as well as approximately 5 per cent each of crude protein and ether extract, they must be regarded as decidedly useful winter foods for animals to which they are acceptable. Both of the chokeberries contain very high percentages of lignin, and this reduces their nutritive value to a point somewhat below that of the mountain ash.

The bittersweet berry is in quite another class from the products just discussed, since it consists mainly of thin walled seeds, with an almost fluid covering of flesh. Its very high contents of protein and ether extract, and relatively high contents of mineral nutrients, constitute it a decidedly concentrated foodstuff.

The two species of blackberry, which are of much the same physical character as the bittersweet, are of lower nutritive value. The composition, as stated here,

represents the value of the blackberry only to animals, such as birds, that grind the small, hard, seeds and thus expose the kernels to the digestive processes. The blackberry contains appreciable quantities of all the classes of nutrients determined, but is most notable for its contents of cellulose and lignin.

The blueberry, deerberry and juneberry should be considered primarily as carbohydrate foods suitable for maintenance purposes. Aside from their content of nitrogen-free extract they are fairly low in nutritive value.

The pulp and skin of the wild cherry is its most important fraction, since the seeds can be utilized only by animals that are able to crack the hard seed coat. The readily available pulp and skin is similar in composition, and nutritive value, to the blueberry, deerberry and juneberry just discussed.

The cockspur thorn is a decidedly inferior foodstuff. It is deficient in protein and fat, high in crude fiber and relatively low in nitrogen-free extract. Furthermore, the nitrogen-free extract includes a considerable proportion of tannin, the nutritive value of which is questionable.

In spite of its high crude fiber the fruit of the cucumber-tree should be of high nutritive value to those animals that accept it as a food. The protein and the ether extract are high, but the dense cellulosic network

that lends rigidity to the fruit, and its aromatic odor, may render it unacceptable to some animals.

The dogwoods, especially the panicled dogwood, are high in ether extract, and they have a moderate content of protein and mineral nutrients. The crude fiber content is high, but not so high as to prevent these products from being important winter reserve foods.

The American elder has a composition that makes it nutritionally superior even to the dogwoods. Its lower crude fiber is associated not, as in many products, with a high content of free extract, but with a relatively high content of protein. The ether extract, although not as high as that of the panicled dogwood, is still higher than that contained in the red-osier dogwood.

The physical characteristics and composition of the frost grape place it into a class with the wild cherry pulp and skin, except that the ether extract is remarkably low. This means that it is mainly a carbohydrate food and therefore of value principally for maintenance purposes. As with other fruits containing large proportions of seeds to soft parts the significance of the analysis of the frost grape to represent its food value to a designated species of animal depends largely on the method of disposal of the seed.

To those animals that can avail themselves of

the whole berry, the black haw as well as the nannyberry are moderately nutritious. The latter contains somewhat less crude fiber than the former, but it also has a lower percentage of ether extract (approximately 9 per cent). Protein is low in both berries and the nitrogen-free extract is high enough to compare favorably with the so-called carbohydrate foods. The black haw contains an unusual amount of tannin, the value of which has not been definitely determined but which seems fairly questionable.

The most abundant constituent of the mountain holly and the winterberry is the nitrogen-free extract, though protein and ether extract are contained in berries in moderate amounts. These berries occupy a position much like that held by the mountain ash and the chokeberries, in that they must be regarded as important winter foods for animals to which they are acceptable.

The spice-bush berry, whether whole or divided into pulp and skin, and seed, is interesting in that it contains approximately 50 per cent ether extract. The extract, however, contains large amounts of aromatic oils which impart a characteristic flavor and odor that might be objectionable to some animals. The content of protein is above average, while the percentages of crude fiber and nitrogen-free extract are decidedly low. This berry, therefore, possesses a decidedly high potential nutritive value.

The sumac berries also are rich in ether extract, though not nearly so rich as the berry of the spice bush. Their content of crude fiber is very high, and the sum of the lignin and cellulose fractions surpasses the crude fiber and amounts to approximately 50 per cent. The nutritive value of these sumacs is presumably further lowered by their high content of tannin. A positive qualification of sumac berries, however, is that they are very resistant to decay; consequently, they should serve as important food reserves, especially during the later winter months when food is scarce.

The hackberry should receive special emphasis because of its unusual content of calcium, which amounts to 12.42 per cent. Magnesium also occurs in an amount greater than that contained in any fruit or berry. The other constituents are present in moderate amounts, with the exception of crude fiber (and lignin and cellulose) which is low.

Nuts

The analyses of all of the nuts represent the meats only, the hulls being considered as without value.

While our acquaintance with nuts is mainly with varieties of high fat content, certain species, as for instance chestnuts, buckeyes, and the acorns are not

especially rich in ether extract. However, in addition to their moderate amounts of fat, they contain substantial quantities of protein and nitrogen-free extract; and they have the further advantage that their hulls are readily rejected. Crude fiber, lignin, cellulose and the minerals are not abundant in nut meats.

The nutritive status of tannin, which occurs in large quantities in acorns, remains to be determined. Obviously foods which are rich in tannin are acceptable to many kinds of animals, but the food habits of other animals raises a question as to the method by which tannin is handled in the digestive processes of animals. In this relation we may bear in mind apparent differences in the metabolism of herbivora, omnivora and carnivora.

The acorns, and in all probability chestnuts, when they are available, are very important winter foods for some forest animals. Their shells render them resistant to decay and, therefore, provide for relative safety in storage for future consumption.

The oil-bearing nuts, hazel-nut, hickory, and walnut, are of high nutritive values, their composition being suggestive of animal flesh. They contain much fat and protein in small bulk, and by virtue of their heavy, protective seed coat are important as winter food reserves for animals that can avail themselves of the kernels. The

richness of the oil-bearing nuts in fat and protein result in their being relatively poor in the other nutrients determined, with the exception of phosphorus.

SUMMARY

Chemical analyses are presented of thirty-five mast foods of the forests of Pennsylvania.

The conventional feed analysis which partitions the food into moisture, crude protein, ether extract, crude fiber, ash and nitrogen-free extract was supplemented by additional determinations of tannin, cellulose, lignin, available protein, calcium, magnesium and phosphorus.

The sum of the lignin and cellulose fractions was found to be invariably higher (124 to 543%) than the single figure for crude fiber, and the value for available protein was always lower than the corresponding figure for crude protein.

The fruits and berries have a fair nutritive value; on the dry basis they contain approximately 5 per cent each of protein and ether extract, and approximately 70 per cent nitrogen-free extract. The remainder consists of moderate amounts of crude fiber and of tannin, the former being of slight and the latter of questionable value, and small amounts of inorganic constituents.

The soft-shelled nuts, which include the acorns, have a percentage composition, and presumably a nutritive value, very much like that of the fruits and berries (dry

basis), except that their content of crude fiber is very low. The acorns are characterized by an especially high tannin content.

The meats of the oil-bearing nuts, such as the hazelnut, are very concentrated foodstuffs, containing much fat and protein in small bulk. They are relatively poor in other nutrients, with the exception of phosphorus.

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BIBLIOGRAPHY

(1) A.O.A.C. 1935
Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists - 4th Ed.

(2) Clarke, I. D., R. W. Frey and H. L. Hyland 1939
Seasonal Variation in Tannin Content of Lespedeza Sericea. J. Agr. Res. 58, 131.

(3) Crampton, E. W. 1939
Unpublished communication.

(4) Crampton, E. W. and L. A. Maynard 1938
The Relation of Cellulose and Lignin Content to the Nutritive Value of Animal Feeds.
J. Nutr. 15, 383-95.

(5) Haas, P. and T. G. Hill 1913
An Introduction to the Chemistry of Plant Products. Longmans, Green and Co., London.

(6) Horwitt, M. K., G. R. Cowgill and L. B. Mendel 1936
The Availability of the Proteins and Inorganic Salts of the Green Leaf. J. Nutr. 12, 237-54.

(7) Horwitt, M. K., G. R. Cowgill and L. B. Mendel 1936
The Availability of the Carbohydrates and Fats of the Green Leaf together with some Observations on Crude Fiber. J. Nutr. 12, 255-273.

(8) Jaffa, M. S. 1901
Nutrition Investigations Among Fruitarians and Chinese. U. S. D. A. Bull. 107, Office of Experiment Stations.

(9) Kumagawa, M. and K. Suto 1908
Ein neues Verfahren zur quantitativen Bestimmung des Fettes und der unverseifbaren Substanzen in tierischem Material nebst der Kritik einiger gebräuchlichen Methoden. Bioch. Z., 8, 212-347.

(10) Kürschner, K. and A. Hanak 1930
The Determination of so-called Crude-Fiber (Cellulose) in Cacao. Z. Untersuch. Lebensm. 59, 484.

(11) Mitchell, A. 1936
A Survey of the Methods of Analyzing Tannins.
Analyst 61, 295 (1936).

(12) Morrison, F. B. 1936
Feeds and Feeding 20th Ed. The Morrison
Publishing Co., Ithaca, N. Y.

(13) Nevens, W. B. 1935
Lespedeza Hay for Dairy Cattle.
J. Dairy Sci. 18, 593.

(14) Oparin, A. and A. Kursanov 1929
Inactivation of Enzymes by Tannins.
Bioch. Z. 209, 181.

(15) Remy, E. 1933
Experimentelle Studien zur Biochemie und
Biologie der Rohfaser. Bioch. Z. 236, 1-18.

(16) Ross, J. H. and A. C. Hill 1929
Determination of Lignin by Formaldehyde and
Sulphuric Acid. Pulp and Paper Mag. Can.,
27, 451.

(17) Sanders, Earl 1939
Pittman-Robertson Project. Statewide (Texas)
Wildlife Survey, Game Management and Demonstration
Project. Phil Goodrum, Supervisor.

(18) Sollman, T. 1932
A Manual of Pharmacology.
W. B. Saunders Co.

(19) Winkler, L. W. 1913
The Volumetric Determination of Ammonia.
Z. angew. Chem. 26, 231-2

(20) Zlatarov, A. and I. D. Popov 1937
Enzyme Chemistry of Tea and Wine.
Z. Untersuch.Lebensm. 73, 154.

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